TOPICAL OUTLINE

VIRGINIA GIS REFERENCE BOOK

General Application Name: Public Works/Service Authority

Product/Service/Function Name: Storm Water Management Program

P/S/F Description:

The National Pollutant Discharge Elimination System (NPDES) requirements imposed by the Clean Water Act have made it a priority for municipalities to develop and implement a comprehensive Storm Water Management Program to deal with potential pollution sources. These programs are initiated to identify problematic or faulty drainage systems, evaluate flooding problems, and provide workable solutions to these problems. By identifying drainage systems and basins that have the most need, localities can model these basins, develop basin-wide master plans and begin to make improvements based on these master plans. GIS provides a means to rapidly evaluate critical basins. Through GIS, information such as soils, land use, transportation, and storm water infrastructure can be integrated as inputs to standard hydrologic models (EPA Storm Water Management Model) used by storm water engineers. Using the results of the model calculations, engineers can make recommendations to improve the storm water drainage system throughout the locality. Hydrologic models can be linked with the GIS to identify and quantify drainage deficiencies and provide a tool to gauge the effects of future development. Mapping, monitoring, modeling, and maintenance are important to storm water management programs and GIS can be used to improve these processes.

Product/Service/Function

1. Spatial Data – Minimum Requirements – Optional Requirements

   Storm water management programs geographically assemble spatial data of a locality into defined drainage basins. In general, public utility or public works departments are responsible for the development and maintenance of paper (hardcopy) or digital maps that depict these basins as lines or polygons on a map with textual records that describe each basin. To conduct a program, a locality should complete a storm water drainage system inventory prior to conducting any analyses of drainage basins. The spatial data characteristics and features that comprise a drainage system are explained more thoroughly in the Storm Water Drainage System Inventory sub-application discussion. This sub-application will be concerned with additional spatial data needed to implement and maintain an on-going storm water management program.

   Minimum Requirements
   The minimum requirements for spatial data include creating digital maps in a GIS of the existing storm water drainage system, impervious surfaces, and drainage basins. The drainage system is based on the location of the drainage system features (i.e., manholes, inlets, catch basins), while impervious surfaces can be derived from features representing building footprints, and paved areas. In addition, the land area of a locality is usually divided into identifiable drainage basins or sub-areas which should be captured in the GIS. At a minimum, all these features for a municipality should be converted into a standard format compliant with one of the major GIS software platforms and stored as line and polygon features in the GIS.

Optional Requirements
Evaluating a storm water management program can be accomplished on a basin-by-basin approach. Optional spatial data requirements for this include:

- Digital Terrain Model (DTM) –coordinates that depict ground elevations that are required for storm water modeling so that accurate, hydrologically correct surface models can be generated.
- Customer Complaints
- Major Outfall Drainage Areas
- Historic Rainfall Data
- Water Quality (NPDES Program sub-category)
- Industrial Facilities (Economic Development General Application)
- Land Use (Planning General Application)
- Soils (Soils Analysis sub-category)
- Floodplains (Environmental Impact Analysis sub-category)

The parentheses next to the spatial data features above indicates the feature should be collected under another application and integrated with data captured for this application. This list of data is by no means all-inclusive, but merely presents a good starting point for localities trying to decide the types of data needed for a storm water management program. One of the obvious benefits to the development of this data is to build a comprehensive master plan for each of the basins in a locality. With this data, a locality can derive data about drainage basins by performing analyses in a GIS.

2. Attribute Data – Minimum Requirements – Optional Requirements

Attribute data refers to descriptive information associated with geographic features or spatial data (i.e., drainage basins). This data is stored as fields in a database or spreadsheet, then entered into the GIS and stored in attribute fields linked to the spatial data.

Minimum Requirements
The following attributes are considered the minimum requirements for attributes pertaining to impervious surface features and drainage basins:

- Unique ID
- Area (acreage or square footage)
- Name (Basins Only)
- Type (Impervious Surfaces Only)

Optional Requirements
Optional requirements include collecting additional attributes for the optional spatial data features identified above in the GIS. According to the spatial data listed, a locality has many options for deciding what attribute data to collect with spatial data in a GIS. Provided below is just a sample of possible attribute data that could be collected and stored with the spatial data in the GIS.

DTM
- Elevation

Customer Complaints
- Address
- Basin Name

- Type

Outfall Drainage Areas
- Area
- Basin Name

Historic Rainfall Data
- Amount
- Year
- Basin Name

3. Data Acquisition Options (integrated with VBMP digital orthos)

   Data acquisition for this application may involve several processes including:

   - Compilation of existing data
   - Digitization
   - Remote Sensing
   - Photogrammetric Mapping
   - GPS Surveys

Communities pursuing a comprehensive storm water management program have found that raster and vector GIS data can be combined to establish and manage storm water infrastructure and conduct modeling and storm water planning.

1. Compilation of existing data means gathering those spatial data layers identified as being collected within other General Applications (i.e., Water Quality, Industrial Facilities, Land Use, Soils, Floodplains). Effective storm water management programs will make use of this existing data with data acquired through the program in modeling scenarios and GIS analyses.

2. Digitization is the method by which boundaries drawn on paper maps are captured in a computer format for a GIS, thereby forming a digital map. One of the first tasks is to digitize the geographic boundaries of drainage basins and impervious surfaces, which are the basic building blocks to the modeling. If available, paper maps can be taped to a digitizing tablet, then the features can be entered into the computer by tracing over the map with a magnetic cursor (similar to a mouse). A scanning machine can also be used to convert the paper maps to digital map images. At a minimum, the hardcopy maps for a municipality should be converted into a standard format compliant with one of the major GIS software platforms. Some localities already have existing digital maps delineating this data in a Computer Aided Design (CAD) software format commonly used in Engineering Departments. Most GIS software has the functionality to import and convert this data into the appropriate GIS format.

   Another option is to use digital orthophotos (i.e. Virginia Base Mapping Orthophotos), with impervious areas clearly visible, to perform digitizing of impervious areas such as polygons.

3. Remote sensing software can be used to distinguish impervious areas from pervious areas based on the spectral properties of the digital imagery (digital orthos). The requirement is that the imagery must be color or color infrared. Remote sensing software is often used to perform image processing techniques such as automatically generating polygons of impervious areas from imagery, which can then be translated to GIS formats. Digital orthophotos, containing ground

features in their true map positions, are another alternative for identifying impervious areas of nonresidential parcels. Once impervious areas are identified, the digital orthophotos can be used as a strong foundation or backdrop for establishing a storm water management program in a GIS, which can be used for storm water system and modeling and basin master planning.

4. Photogrammetric mapping involves using specialized technology to capture digital data representing features as seen on orthophotography. Aerial triangulation of the orthophotography is used as the basis for generating DTM data. If DTM data is not available, USGS digital elevation models (DEM) can be used. However, USGS DEMs have an accuracy of +/-30 meters; therefore, the resulting modeling data would only be reliable for regional planning and not detailed basin planning.

5. The final process is to use GPS surveys to precisely locate drainage basins or other features pertinent to storm water management. GPS equipment takes advantage of sophisticated technology to capture the exact latitude/longitude position of features using satellites orbiting the Earth.

4. Data Conflation Options (integrated with VBMP digital orthos)

When creating a digitial map through digitization of paper maps, conflation is the process of updating storm water features in a GIS to match the most accurate spatial and attribute sources. To ensure an accurate fit, spatial data can be conflated or matched to actual ground and cultural features visible in the digital orthophotography (i.e., VBMP digital orthos) such as streets or natural drainage patterns. Up-to-date digital orthophotography is the best data source for spatial data conflation.

5. GUI/Programming Options

A GUI or Graphical User Interface is the graphics a computer user sees on the computer screen when they run a computer program. Many of the leading GIS software platforms have GUI's that have similar features to Microsoft Word including buttons and toolbars that initiate different processes. Depending on the GIS software platform used to create and maintain the storm water management program data, a municipality has the ability to develop customized programs that alter the look of the GUI and streamline certain processes. An example of this would be the development of a program that allows a user to enter a drainage basin name or ID, and have the program display all the customer complaints within the selected basin.

6. Internet Functionality and Options

The internet offers an excellent medium for distributing data and information in a public domain. By utilizing the internet, a locality can provide access to data contained in the GIS to any citizen with a computer and internet connection. This functionality can dramatically reduce the time spent answering citizen inquiries concerning utility information and increase employee productivity. For example, a municipality could develop a mapping website that displays land use data and percent of impervious surface estimates for the user selected drainage basins areas.

A locality must be cognizant of the security issues surrounding the viewing of sensitive data over the internet. Only data deemed suitable for public viewing and that won't compromise the security of a locality's storm water system should be included in a mapping website. System administration procedures must be in place to monitor the security of the mapping website and manage the internet services.

7. Minimum Technical Requirements – Optimum Technical Requirements

The following minimum technical requirements apply to the hardware/software configuration recommended to implement and maintain storm water management data in a GIS.

Hardware
- IBM PC or compatible computer
- Windows NT service pack 6a, Windows 2000 service pack 2, Windows XP Home Edition, or Windows XP Professional Edition
- PC with a fast Pentium chip (450 Mhz minimum)
- 128MB RAM minimum
- 10 GB hard drive
- Fast disks (SCSI as opposed to IDE)
- True color monitor with a minimum of 16MB video card
- Paging File (Swap Space) at a minimum of 300MB.

Software
- Windows, Macintosh, or Unix compatible
- GIS software (i.e., ESRI, Intergraph, Autodesk)

The following optimum technical requirements apply to the hardware/software configuration recommended to implement and maintain storm water management data in a GIS.

Hardware
- Windows NT service pack 6a or Windows 2000 service pack 2
- PC with a fast Pentium chip (750Mhz or higher recommended)
- 256MB RAM or above
- 20 – 40 GB hard drive
- Fast disks (SCSI as opposed to IDE)
- True color monitor with a minimum of 32 MB video card
- Paging File (Swap Space) at a minimum of 300MB.

Software
- Windows compatible
- ESRI GIS software (consistent with other localities in Virginia)
- Specialized Water and Sewer Modeling software from ESRI business partners
- Remote Sensing Software

8. Administrative/Management Requirements

Several issues must be addressed when determining the management requirements for the initial implementation and management of a storm water management program. Initially, a locality must decide whether to develop and maintain the GIS data by hiring a consultant or with in-house staff. This decision will depend on factors such as budgetary issues, staff expertise, staff availability, scheduling, and technical resources of the locality. Many localities in Virginia maintain some of the storm water mapping information internally because the demands of creating and maintaining this information are not as large as developing other types of GIS data (i.e., parcel mapping). On the other hand, spatial data such as DTM's are usually developed by a consultant. Many localities rely on outside assistance to maintain successful storm water management programs because the project

demands of monitoring and managing these programs for compliance with federal permitting programs can often exceed the resources of a locality.

If a locality decides to create and maintain storm water management features in a GIS, personnel must be identified for the project. Conducting a strategic plan up-front will allow a locality to identify current staff that may aid in the development of the GIS. A locality should start by selecting staff members with an interest and background in geography, mapping, computers, or engineering. Personnel with this kind of experience usually understand the basic concepts behind mapping spatial data and will probably learn GIS much faster than other employees. Personnel from Planning, Economic Development, Engineering, Public Works, and Public Utility Departments are ideal candidates for GIS training. Ideally, a locality will designate staff members from the departments responsible for utility maintenance (i.e., Public Utility or Public Works) to manage the effort.

Different types of staff will be needed to develop GIS data and maintain it. First, a qualified manager with experience working with spatial data should be assigned to oversee the development of a municipality's spatial data and guide the policies governing the use of this data. For a locality in the early stages of GIS development and with little GIS expertise, this means hiring a GIS manager from external sources. Second, selected staff members from the departments identified above should be trained to complete tasks commonly performed in a GIS. This includes digitizing maps, creating GIS data layers, assigning attributes to GIS features, and creating map products for local planning, maintenance, and reporting purposes. Overall, a locality will need one GIS manager and 1-2 staff members dedicated to storm water management depending on the demands of the program.

9. Cost – Cost/Benefit

The costs associated with this application can constitute a significant portion of the overall costs a locality will need to allocate for GIS projects. Most of the costs associated with developing GIS data for this application will involve the conversion of data, while secondary costs will occur from modeling activities. While the costs associated with developing this GIS data can widely vary depending on the spatial extent of the municipality and the number of drainage areas to be monitored and managed, costs can be separated into two phases:

- Data Acquisition (Development) Costs
- Data Operational Costs

Development costs will depend on the data acquisition chosen. For the purposes of the estimates contained herein, it is assumed that a locality will employ a combination of processes identified in data acquisition options to collect GIS data for every spatial data layer listed. This cost is dramatically reduced if a locality already has existing digital CAD data. It is important to note these costs vary based on the number of the storm water basins and the number of attributes to be added to the GIS data. Additional start-up costs for a locality may involve investing in the necessary hardware and software, if needed. Hardware costs include a dedicated computer server for the GIS and PC's for the staff assigned to work on the GIS. Suitable computer servers can range in cost from $10,000 - $50,000, depending on the technical specifications like processor speed and memory. PC's that meet the minimum technical requirements to operate GIS software range in cost from $800 - $2000. GIS software costs will vary depending on the software package(s) purchased. Current prices (per copy of software) for GIS software are $1000 - $1500 for low-end products, $4000- $5000 for middle-end products, and $10,000 - $12,000 for high-end products.

Provided below is a summary of the cost range for common tasks performed during a GIS implementation of storm water information, assuming the GIS program is just beginning:

Needs Analysis – Needs Assessment; Data Survey; Management Plan; System Implementation Plan	$25,000 - $50,000
Hardware – 1 Server and 2 Workstations (if needed)	$10,000 - $40,000
Software – GIS Software	$10,000 - $20,000
Peripherals – Plotters; Printers; Scanners; Digitizers; GPS Equipment (if needed)	$20,000 - $50,000
Staffing (Annual) – 1 GIS Manager, 2 GIS Technician	$50,000 - $120,000
Training	$10,000 - $40,000
Data Acquisition	$50,000 - $200,000
Application Development for Storm Water Analysis	$10,000 - $150,000
Storm Water Modeling Integration with GIS	$50,000 – $300,000
Future Consulting	$50,000 - $500,000

After the implementation is complete, a municipality must adopt operational procedures to ensure the currency of the program is protected through regular maintenance of the data in the GIS databases. Operational costs associated with data maintenance will be the amount of staff time dedicated to this effort. A locality should have at least 1 staff member (1 technician) working part-time updating service area changes, so the costs would be the salary of this staff member.

Quantifying the major GIS benefits is very difficult, but there are some benchmark studies that document productivity improvements and cost savings produced by a GIS. One of the studies most referenced for cost and benefit data related to GIS is the *Joint Nordic Project – Community Benefit of Digital Spatial Information* cited in *The GIS Book (George B. Korte, 1997)*. This study collected information on the costs and benefits of 16 GIS projects. The following findings offer general estimate ratios for benefit/cost (B:C) returns:

- GIS is used only for digital mapping of service area information – **1:1** return
- GIS used for planning and engineering tasks – **2:1** return
- All paper maps converted to digital maps – **3:1** return
- GIS is used to create and maintain all spatial data – **4:1** return
- GIS data stored in one database and shared by all user departments – **4:1** return
- An automated system in GIS for localities with poor quality maps and maintenance procedures – **7:1** return
- GIS used for spatial analysis – **10:1** return

10. Standards/Guidelines Summary

Standards for storm water data vary depending on the locality. In essence, the data is only as accurate as the source it came from, which can include paper maps and/or CAD data. The majority of municipal paper maps are developed at scales between 1 inch = 200 feet and 1 inch = 400 feet. Digital maps based on these sources will only be as accurate as the National Map Accuracy Standards (NMAS) for data sources at these scales. There are no pre-defined accuracy requirements for GIS storm water feature data, so accuracy specifications usually depend on a municipality's requirements and day-to-day information needs. It is recommended that a municipality utilize digital orthophotography as a base map and a source for geo-referencing maps. In the State of Virginia, many municipalities geo-reference their GIS data in the Virginia State Plane coordinate system (NAD 1983).

11. Startup Procedures/Steps

Building a successful GIS database should consist of several startup procedures including planning the project, communicating the project plan to all interested parties, gathering data sources and resources, setting achievable milestones, and gaining manager support. The up-front planning of the conversion effort must accomplish the following:

- Establish goals and strategies
- Perform a needs assessment with end users in the Public Utility and Public Works Departments
- Determine data requirements based on the needs analysis
- Prepare a budget and project timeline
- Determine staff to maintain the data

Based on the cost estimates for outsourcing the GIS work to a consultant, the in-house staff expertise, and GIS budget, a locality must determine whether to perform the work internally or have a consultant complete the work. Once this decision is made, a locality must invest in the hardware and software needed to run the GIS. The number of computers and number of software packages to purchase should be specified in a needs analysis. Many localities in Virginia have hired outside consultants to prepare the needs analysis and storm water management plans that will guide the future GIS, including the City of Richmond, City of Suffolk, and City of Virginia Beach.

12. Estimated Time Line and/or Implementation (stand alone) Schedule

Estimating the time line or schedule of a storm water management project will depend on a number of factors specific to a municipality, including:

- Size of the municipality
- Density of drainage basins covering the municipality
- Methodology of conversion
- Staff expertise performing the work
- Personnel dedicated to the project
- Funding

A reasonable time line for developing a comprehensive storm water management program that integrates GIS with modeling is between 1-2 years.

13. Best Practice Examples in Virginia

Several municipalities and organizations have implemented storm water management programs utilizing GIS technology. The Navy Public Works Center at the Norfolk Naval Base conducted a Storm Water Drainage and Flood Evaluation Study using GIS and modeling technologies. The base hydrology produced by appropriate storm events was mapped and the hydraulic capacity of the existing Naval Base Norfolk storm drainage system analyzed. Recommendations were developed based on a comprehensive modeling of the storm drainage system's capacity to handle a storm event happening concurrent with a high tide level. In Poquoson City, a detailed and comprehensive hydrologic & hydraulic analysis was conducted for the Oxford Run Drainage Study. The existing Storm Water Management (SWM) Best Management Practices (BMPs) along Wythe Creek Road and in the City of Poquoson were included in the hydrologic model. The proposed regional SWM pond and the proposed residential development known as "The Villas" was also included in the hydrologic analysis. The computed water surface elevations and profiles show the effect of tidal influence on Oxford Run. Future analysis will determine

alternates for widening the existing ditch. The effect of tidal influence in Oxford Run will be a major factor in determining the selection of feasible widening options.

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